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ABSTRACT

How measurement systems developed is briefly reviewed, followed by comments on the international conversion to the metric system and a lengthier discussion of the history of the metric controversy in the U.S. Statements made by supporters of the customary and metric systems are listed. The role of education is detailed in terms of teacher preparation, curriculum, and instructional materials. A list of 113 references is included. (MS)

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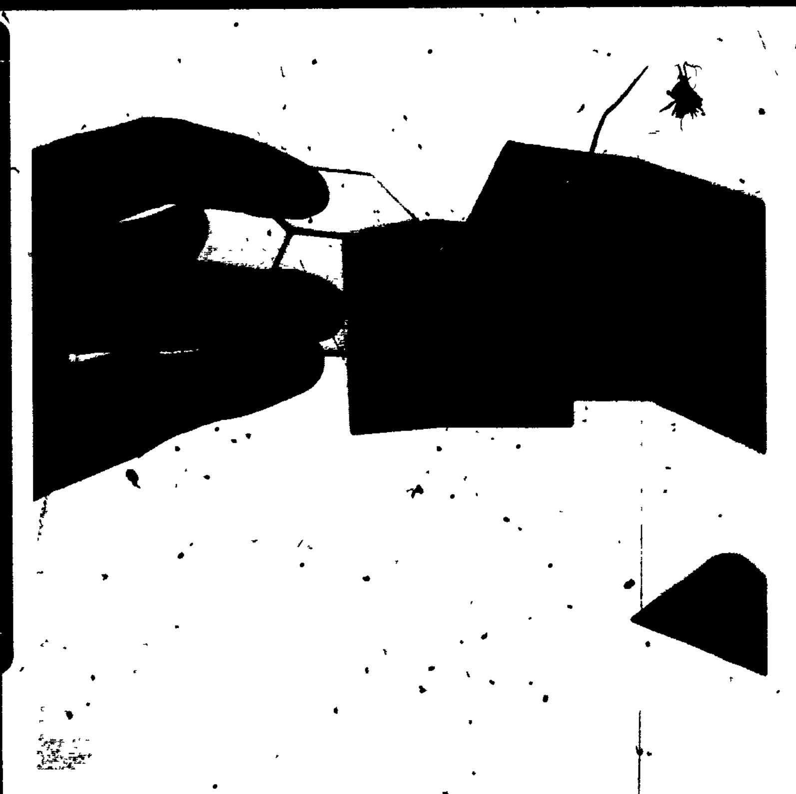
What Research Says to the Teacher

Metric Education

by Sheralyn S Goldbecker



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CONTENTS

Sheralyn S. Goldbecker, an educational writer and researcher, is the author of *Reading: Instructional Approaches* and *Values Teaching*.

The manuscript was reviewed by Patricia A. Gregory, fourth-grade teacher, Cedar School, Hanover, Massachusetts.

THE DEVELOPMENT OF MEASUREMENT SYSTEMS

Systems of measurement were developed by early cultures to meet the need for a means of communication, for a means of expressing specific quantities, periods of time, distances, and the like The systems of weights and measures these cultures created were among their earliest and most important tools The first such standards were related to familiar things—to natural phenomena such as the phases of the moon, and to parts or characteristics of the human body such as the length of one's stride And because there was little exchange of goods and ideas among early peoples, numerous discrete measurement systems evolved and grew in complexity as the cultures developed

As contact between cultures increased, measurement systems were modified and merged so that standards would be meaningful to larger groups of people, thus facilitating the growing exchange of goods and knowledge Tradition and provincialism encouraged the proliferation of systems of measurement, particularly in Europe This complexity was further complicated by the practice of creating many units unique to the objects being measured, as hands, for example, were and still are used to measure the height of a horse

Among the systems that evolved in this generally haphazard manner was the imperial system, formerly the primary system of weights and measures in Great Britain It includes elements of the Babylonian, Egyptian, Roman, Anglo-Saxon, and Norman French systems which were gradually standardized into a loosely related structure And it is this system that the United States largely adopted as the *customary system* (also referred to as the British, English, British/American, or American system) of inches, feet, pounds, dry and liquid quarts, and so on

The *metric* (meaning "measuring") *system*—a system of weights and measures based on the number 10—also has evolved and changed over the centuries, but in a much more deliberate manner. During the sixteenth century Simon Stevin, a Flemish mathematician, first published a theory of decimal fractions and proposed a decimal measurement system, thus laying the theoretical foundation for the development of the metric system.*(1) Then in 1670 Gabriel Mouton of France suggested a decimal

*Numbers in parentheses appearing in the text refer to Selected Research References which begin on page 29

system of weights and measures using the meter, the basic unit of length based on a physical constant, a section of the earth's circumference By 1790 the French Academy had developed a coordinated, decimally related system of measurement for length, area, volume, and mass based on this principle, using the metric units of meters, liters, and grams with the prefixes milli-, centi-, and deci- indicating subdivisions of these units, and deca-, hecto-, and kilo- indicating multiples

As the use of the metric system spread, there was need of greater standardization, so in 1875, the representatives of 17 nations, meeting in Paris, set specific standards for the meter and the kilogram, and established the International Bureau of Weights and Measures Eventually a General Conference of Weights and Measures was formed to control this Bureau The Conference continues to meet every six years, and in 1960 it presented a modernized metric system called Le Système International d'Unités (the International System of Units) or SI, redefining the meter in terms of a wavelength of light.

A METRIC WORLD

International Conversion to the Metric System

The adoption, or commitment to adoption, of the metric system is now almost universal The French officially adopted it in 1795 following the French Revolution—partially because of wide variations in their existing system, resulting in frauds and disagreements over errors. Another reason for the adoption may have been antiroyalist sentiment against any reminders of the feudal system: the yard had been defined as the distance from Henri's nose to his thumb. (30) But even then, the metric system was not an immediate success, and France eventually had to make its use compulsory in 1840 .

European and South American nations did gradually accept the metric system, but Gerardus Vervoort (106) indicates that adoption of the system may have been hindered by the enthusiasm of metric supporters in applying the system to areas other than weights and measures For example, some suggested a new calendar, beginning with the year one, with 10-day weeks and no Sabbath, thus associating the metric system

with atheism. And after the Napoleonic wars, there existed a reluctance in many countries to accept anything French

Japan began its metric conversion in 1921, not fully completing it until about 1962, and China converted after World War II Then in 1965 Great Britain began its conversion or "metrication," followed by South Africa in 1966 and Australia, New Zealand, and Canada in 1970, leaving the United States as the only major industrialized nation uncommitted to adoption of the metric system

The Metric Controversy in the United States

During this period of international conversion to metrics, the United States took no definitive action—but certainly not because of lack of support for adoption of the metric system as our primary system of weights and measures The controversy over whether or not to change to the metric system has continued throughout our history

In 1790 Secretary of State Thomas Jefferson prepared and presented to Congress unified systems of weights and measures and of coinage—both based on the decimal system The monetary system was adopted, and although it was discussed over a period of six years, no action was taken on Jefferson's measurement system, which he based on an absolute standard found in the physical universe—the movement of a pendulum rod over 2 seconds In this case, the standard length was to be a rod about 58 7 inches long, which would be divided into 5 new feet, each consisting of 10 new inches The standard mass, called an ounce, was to be one cubic inch of rain water Each basic unit of length, mass, and volume was to be related to the others, and all multiples and subdivisions were to be decimally related

Then in 1821 Secretary of State John Quincy Adams issued the *Report Upon Weights and Measures* in which he discussed the advantages and disadvantages of the metric and customary systems He found the metric system to have theoretical advantages, but concluded that its adoption was not practicable at the time—partly because of our commerce with nonmetric Great Britain Instead he suggested standardization within the English framework

Leaders in politics, science, education, and business continued to support the metric system, and in 1866 it was made legal, but not mandatory, to use metric measurements in the United States It was thought at the time that this step would bring about metric conversion, but

people remained reluctant to change unless "everyone" did. In 1893, the metric meter and kilogram, however, were made the standards by which our customary yard and pound are respectively defined

Congressional hearings on metric conversion began once more in the 1920's, again without resulting legislation, and various types of metric legislation have been introduced in every session of Congress since about 1960 The Metric Study bill, approved in 1968, called for an investigation—the U S Metric Study—of the relative merits of the metric system The final report of the three-year, $2 5-million study, *A Metric America. A Decision Whose Time Has Come* (27), was submitted to Congress in 1971 by Secretary of Commerce Maurice H Stans This report supported metric conversion, recommending deliberate and careful voluntary change over a 10-year period, with a national program to be coordinated by an official body representative of all segments of the economy The report further stated that conversion costs should "lie where they fall" with no government reimbursement, as an incentive to keep costs down and as a means of ensuring that those who would be benefited would be the ones to bear the costs It also recommended that an immediate priority be given to educating students in school and the public as a whole to think in metric terms

In spite of the report, legislation calling for voluntary conversion was again defeated in 1972 and 1973 Then the passage of the Education Amendments of 1974 finally gave impetus to conversion, encouraging educational institutions to prepare students to use the metric system To facilitate this, the Commissioner of Education was authorized to spend $10 million for each fiscal year ending before July 1, 1978, for contracts and grants to educational institutions, state and local education agencies, and public and private nonprofit groups to carry out the intent of the legislation. And finally, in December 1975, legislation calling for a gradual, voluntary conversion and the eventual appointment by the President of a metric board was approved by Congress.

Why has the controversy over "going metric" continued so long in the United States? Why has the movement to metric conversion been so cautious? Arguments for and against metric conversion are discussed more fully in many of the Suggested Readings, but a summary of the major points is presented below to indicate some of the problems we will face in learning to think metric.

People in the United States have not been accustomed to adapting to the systems of other countries—whether languages, customs, or

measurements—so such a change may appear traumatic in nature. Supporters of the customary system conclude that:

1. The cost of metric conversion would be from $50-100 billion. (5)
2. Such a formidable change is not worth the great cost when the United States has become rich, successful, and technologically advanced using customary measurements.
3. Our export trade with metric countries is not significant enough to warrant such a disruption of our economy.
4. Workers would have to be retrained, and those workers who own their own tools would have to replace many of them with metric tools.
5. The nation would be handicapped during the transition by having to be bilingual—i.e., familiar with both customary and metric measures, industry would have to maintain double inventories, and consumers might not understand what they were getting in their purchases.
6. Since computers that would handle the more complicated problems can work with any units, there would be no reason to change to facilitate measurement-related computations.
7. A change from measures based on natural, familiar characteristics such as the length of a person's foot, to the artificial metric measures would cause fear and anxiety among the public.
8. Having to work with unfamiliar units might result in mistakes that would threaten health or safety.
9. The customary system is easier to work with, because it consists of simple, one-syllable terms.
10. It is actually often easier to do simple computations mentally with customary units than it would be with metric ones.

The argument that we need not change systems because such major trading partners as Great Britain and Canada are nonmetric is no longer valid as Great Britain nears completion of metrication and Canada is committed to being fully metric by about 1980.

Proponents of the metric system find that:

1. Changing to the metric system is necessary to maintain a favorable balance of trade, and conversion would thus stimulate the economy. According to Frances Lauer of the Metric Association, "Every President has had a plan for switching to metric. But for years Congress was dominated by agricultural people who could not see that we were becoming a highly technological nation." (34)

2. The metric system is logically planned and easy to learn, because the average person would use only about 10 basic units (as compared with over 50 customary units). Once these units are learned, they are also easier to remember and work with because of the decimal relationship among units and the coordination of measures for length, area, volume, and mass
3. The metric system can be quickly and painlessly taught to the public through product and public service advertising, adult education courses, etc
4. Because decimals are easier to learn and to compute with than fractions, increased accuracy in all areas would result
5. Conversion to metrics provides an opportunity to eliminate superfluous product sizes and parts, and to create a more rational marketplace. Price comparisons would be facilitated for consumers if packaging were rationalized into even decimal sizes
6. Using liters and grams would eliminate existing confusion between such units as dry and fluid ounces, pints, and quarts.
7. U.S adoption of the metric system would allow our greater participation in establishing international engineering standards and would facilitate international cooperation among scientists in all fields
8. The actual costs of conversion are hard to identify beforehand, so opponents' estimates may be totally wrong. The United States is now drifting metric, so there will be conversion costs anyway—but a national, coordinated plan would mean net savings (80)
9. Metric conversion will employ the "rule of reason." It would not mean a sudden change to the practice of cooking by weight used in many metric countries, and such familiar things as the 100-yard football field would remain. Also, exact conversion from customary to metric units would not be made. For example, car owners would buy one liter of oil rather than 0.946 liter, the exact conversion from one quart.

The major objections to metric conversion that specifically relate to education generally involve anticipated costs

1. Changing textbooks and equipment would cost $1 billion over three to five years (27)
2. Time and money would be involved in retraining teachers and revising curricula
3. Students would become confused by having to learn both customary

and metric units during the transition, and such dual instruction would take more class time.

But while there would be problems related to education, none would be insurmountable, according to metric supporters:

1. Revision of the curriculum to ensure that students learn to think in metric rather than customary terms would provide an opportunity for complete revision of the way students are taught about measurement as well as of the system they learn to use.
2. A certain amount of time-saving from reduced treatment of fractions and the dropping of conversion among measurement systems would result. Authorities have also found that specific instruction on conversion *within* the customary system is required, but time would not have to be devoted to this if the metric system were in use. (83) Some estimate that two years of arithmetic teaching time could be saved at the elementary level; some say 10%, others 25%. (29) There would be little, if any, saving during the transition because as long as there is not complete conversion in the public area, students would have to learn both measurement systems. There would be some saving of time in upper-level science courses, however, since the metric system would not have to be *taught* in secondary schools.
3. Because the metric system would save teaching time, it would also save money. Some estimates place the savings at $30 per pupil. (34) Frank Donovan (29) quotes Fred J. Helgren of the Metric Association as finding estimates made in the 1960's of $15-per-pupil-per-year savings inaccurate, because they do not account for the fact that some teaching of fractions must still take place. And in reality, there would not be a dollar savings since the time and money gained would be used elsewhere in the curriculum, perhaps giving students more time to explore individual interests. (90)
4. Extra costs for updated texts and equipment would be minimal in a 10-year conversion. Textbooks are normally revised about every five years; and reference materials in libraries would become dated and need replacement after 10 years anyway. And if equipment such as that in school shops could not be adapted to metric units, it could be replaced as needed, with older equipment being replaced first, over the 10-year cycle, thus reducing additional cost and providing a school the chance to revamp the learning environment.
5. Costs for retraining teachers would also not be great because this could be done through regular in-service and continuing education

programs and workshops. And eventually there would be no need for such training as those schooled in the metric system entered the profession.

6. There is less to learn in the metric system than in the customary system; the decimal relationships of multiples and subdivisions simplify teaching and are easier for students to work with than fractions and mixed numbers are. This greater simplicity results in greater accuracy.
7. Slower students would be able to learn the metric system more easily than they do the customary system, because they would be working with whole numbers (However, Roxee W Joly (50) reports that such claims hold for instruction in the early grades but not in secondary-level sciences.)

Certainly the United States is not moving blindly into metric adoption. In addition to all the data gathered on metric conversion problems, needs, attitudes, goals, etc, by the Metric Study, the experiences of other countries can teach us about the possible successes and failures of conversion. In 1973 the National Institute of Education funded an American Institutes of Research (AIR) study (20) of the educational problems faced by Great Britain, Australia, New Zealand, South Africa, and Canada. Among the things that have been learned from such studies is the importance of scheduling. Because Great Britain fell behind schedule (generally not the fault of the education system), students suffered the consequences by having to become totally involved in the metric system in school while living in a nonmetric society. And in Japan metric conversion began in 1921 when the metric system was introduced in the primary schools, but it was not completed until about 1962 because of the lack of a strong plan and a firm schedule. While the early introduction of metrics into the schools facilitated the final change, it was not enough by itself to bring about conversion. (27)

In looking at cost factors, the AIR study (20) investigated claims of savings of up to 25% in time spent on arithmetic and dollar savings of up to $500 million per year. No evidence was found to support or deny these claims. (19) But Donovan (29) reports that in India estimates of probable costs ran far ahead of actual expenditures. Introduction of the metric system in Indian schools was actually easier than expected, and students learned the system without difficulty, even though proper texts were hard to obtain.

Another clear lesson concerns the importance of communication.

Great Britain achieved success earlier in industry than in the consumer sector. As a result, recommendations would include getting the public involved and indoctrinated early in metrication to avoid the problems the British faced living in a half-metric, half-imperial environment (30) As a means of promoting early and extensive public awareness, Australia and Canada used such methods as employing metrics in sports and weather reports "And in Japan the Metric System Promotion Committee distributed pamphlets and posters and used mass media to educate consumers and workers" (27)

THE ROLE OF EDUCATION

Experience in the United States and abroad points to the education system as a key factor in successful metric conversion Surveys conducted as part of the Metric Study showed that the more familiar people are with the metric system, the more they favor its adoption as our primary form of measurement. (27)

In Great Britain industry led metrication with the support of government, and education followed. In the United States most industrial firms surveyed during the Metric Study saw metric conversion to be in the national interest, but few were prepared to assume leadership in this conversion. "In this situation, it seems clear that education could play a much different role; and if a nationally coordinated program of going metric were to be undertaken in the U.S., then it would be appropriate for education to lead." (90)

As we consider the role education will be expected to play in metric conversion, we see that the areas of teacher preparation, a well-planned curriculum, and adequate instructional materials will be crucial to the success of the conversion

Teacher Preparation

In order to instruct students adequately, teachers must be thoroughly knowledgeable of and conversant with metrics, in short, they must be comfortable enough with the system to *think metric*. Educators agree that some type of in-service training will be needed by teachers in all fields—with elementary teachers, especially those in self-contained

classrooms, needing the most intensive instruction and secondary science and mathematics teachers needing minimal refresher courses

Estimates on the amount of training vary During the 1970 Education Conference of the Metric Study, John F Kourmadas of the National Association of Secondary School Principals (NASSP) estimated that 8-15 hours of in-service training would be needed (90), and Joseph R Caravella (17) reports that preliminary results from a pilot metric education program in Hawaii confirmed the Metric Study's estimate that training can be done in 10-15 hours

Albert B Chalupsky and Jack J. Crawford (19) think the initial emphasis of such training should be on giving teachers an awareness both of the purpose of and the need for metric conversion and showing them how such a change will affect their lives and those of their students They also find it essential to reassure teachers that metrics are not difficult to learn and that a change to the metric system is not threatening The final report of the Metric Study (27) states that "Educators are nearly unanimous in their endorsement of the metric system," that "Virtually all the individuals in the educational system . make some use of the metric system and are in favor of a planned conversion program " But NEA finds that while many educators have supported metric conversion, this support has not been universal or "militantly aggressive " (90) By identifying and analyzing the reasons why teachers might resist metric conversion (i e , they are "too old" to learn a new system, or they worry about making conversions between measurement systems which are not really necessary if one thinks metric), Chalupsky and Crawford (19) conclude that more effective teacher training strategies can be designed to overcome these problems

There is also agreement that teachers should be taught as they will teach their students and that only by actually working with the metric system in a laboratory or classroom situation can they become familiar with it In preparing to go metric in the public schools, Maryland educators proposed a two-and-a-half to three-day concentrated workshop, with half the time spent on learning the system and half spent actually using it (71) Plans for Hawaii's pilot metric program included 8 to 15 hours of condensed metric training just prior to the actual teaching of the system, with emphasis on teaching strategies for an activity approach. After experimental testing of the program, it was concluded that a 12-hour workshop actively involving teachers in estimating and measuring activities is adequate (54), and that workshops stressing such activity

strategies are the most successful (17)

Some of the various in-service strategies suggested during the Metric Study's Education Conference (90) include

1 A half-day workshop on the advantages and disadvantages of the metric system and its basic units, followed by five to eight two-hour sessions with a master teacher to get practical experience in using metrics

2 Broadcasts of four to six videotapes (20-30 minutes long) based on successful teaching experiments, each followed immediately by an hour of measurement activities, and two meetings with an instructor to clarify teaching strategies and provide further activities This training would take place over two weeks and could be supplemented with monthly broadcasts in the same format

3 A gradual type of approach with workshops conducted half a day each week throughout the school year

Jon L Higgins (41) outlines a plan for teachers to learn metrics that directly parallels strategies suggested for students Teachers would begin working with arbitrary, nonstandard measurement units to see the need for standard measurements, and then move to multiples and subdivisions of these arbitrary units, becoming involved in selecting the appropriate unit for the task at hand Instruction on metrics utilizing units of length and area would then follow In this way, the teachers would become familiar with the relationships of the meter, decimeter, and centimeter and then the millimeter and kilometer Finally, the teachers would move to units of volume and mass, learning the interrelationships among all three types of metric measurement

But who is to provide this instruction to the individual teacher? The National Science Teachers Association (NSTA) points up the need for leadership training to be given to selected teachers, perhaps as part of existing college programs for science teachers, who would in turn train local in-service groups. (90) The idea of a teacher-of-teachers approach in such an ever-broadening pyramid extending down to the local elementary school level is recurrent throughout the literature

Certainly, college and university departments of teacher education can carry out an important function in training individuals In a survey reported by Edward Kabakjian (52) of 50 industrial arts, 48 vocational education, and 48 home economics teacher preparation departments, respondents felt the responsibility for metric preservice and in-service education should lie with the teacher education department.

John R Lindbeck (56) outlines a number of recommendations relative to industrial arts teacher education, but which could have application in any other field.

1 One person in the teacher education department should become a metric expert on all aspects of the system, collecting metric information and materials, attending appropriate conferences, and helping other faculty members become metrically competent
2 The department should train itself and then provide preservice education for its students.
3 The department should assume regional leadership for in-service training, planning programs designed to meet teachers' needs. Metric awareness programs to make teachers cognizant of impending changes, issues, and educational needs would be followed by actual in-service training through workshops, summer programs, seminars, and regular course offerings
4 The department should employ qualified consultants as needed to work with the faculty to be sure the metric system is understood and used properly

As an example of how such a program would work, Lindbeck described the Center for Metric Education and Studies at Western Michigan University, which organized an advisory group of metric educators from many fields. To prepare group members to work with teachers and teacher educators in preservice and in-service training programs, the group underwent six two-hour training seminars. Then members went on to speak to education groups, hold teacher education seminars, work with school districts' model programs, and teach summer courses—while still continuing to meet to share and evaluate experiences and materials and to continue their studies

Another important factor in teacher preparation is the professional association Chalupsky and Crawford (19) see the education association in particular as exerting a positive force in bringing about a smooth metric conversion, and Helgren (40) encourages teachers to join those organizations that will provide them with metric information, sources of instructional aids, and news on teaching developments Of the responding departments in the survey reported by Kabakjian (52), 84% hoped that professional associations would assume a leadership role in training teachers, leading to the author's recommendation that associations should develop guidelines for preservice and in-service training, develop

instructional aids and materials as models for individual departments to duplicate, hold state and national workshops for teacher educators, and provide workshops for their state associations. As an example, NEA is committed to help teachers go metric through publishing articles in *Today's Education* and participating in meetings on metric education. (24)

Curriculum

Before looking at necessary changes in the curriculum resulting from metric conversion, it is helpful to examine first the current status of metric education

Apparently most students are being exposed to metrics to some extent During the 1970 Education Conference, NSTA reported that few elementary science programs used only the customary system, that most recent junior high programs used the metric system predominantly or exclusively, and that the metric system was used almost exclusively in high school biology, chemistry, and physics (90) Since that time, a number of states have begun metric education programs in the schools and a number of metric research projects have been funded

In 1972 the Hawaii State Legislature requested the University of Hawaii's College of Education to design a pilot program for teaching metrics, with the hope of complete conversion in the schools by 1978-79 (17, 54) And in 1973 the Maryland State Board of Education adopted the policy of complete conversion to metrics in the schools between 1974 and 1980. (17, 71) By mid-1974 49 states had some type of formal metric instruction in the public schools, 6 states had laws directing action on metric instruction, and 13 state boards of education had adopted "go metric" resolutions (19)

Among the metric research programs funded through the U S. Office of Education (USOE) are two projects at the Center for Metric Education (later replaced by the Center for Metric Education and Studies) at Western Michigan University. one on conversion in vocational education, including development of bilingual packages and materials for the handicapped; and one to develop preservice and in-service training materials for industrial-vocational teachers The Ohio State University was given a three-year USOE contract to design instructional materials in vocational and technical education and to hold regional training workshops; and the North Carolina Department of Public Instruction was funded through

ESEA to develop an overall plan and working models for metric transition in such areas as curriculum and staff development and coordination with other sectors of society

In 1973 the National Science Foundation contracted with the University of Minnesota to study alternative strategies for metric instruction, and the Mathematics Basic Skills Development Project of the Minneapolis Public Schools has created instructional materials, objectives, tests, and enrichment activities for grades 7 through 12

Of particular importance was the USOE-sponsored Interstate Consortium on Metric Education, directed by the Mathematics Education Task Force of the California State Department of Education Begun in 1974, the Consortium sought to develop uniform policies and schedules for adoption of texts and instructional materials, teacher training, and implementation of metric programs through a series of workshops for states with central or state-level text adoption laws or policies. Of the 27 states and territories participating, all agreed to introduce supplementary metric materials in the schools by 1977 and to have texts and materials with the metric system as the primary system available in the schools by 1979, with the transition virtually complete by 1980

Certainly these and other current programs should be concerned with correcting the shortcomings of previous metric instruction NEA has pointed out such faults as the brief and superficial coverage given metrics at the elementary level and its treatment as a system "some people use." (90) Helgren (40) also concludes that because the metric system has not been studied as a system by itself, people are not learning to think in metric terms. Many texts have provided only a single instructional unit on metrics, usually involving only conversion exercises, and since this unit is often at the end of the text, it is seldom taught.

Conversion to the metric system gives educators a chance to look carefully at the curriculum as a whole so that teaching and learning of metric units will be combined with better ways of teaching and learning measurement. Higgins (43) reports that research has shown that teaching measurement is more complex than has commonly been assumed, and that success requires certain prerequisite skills and understandings on the part of the students The curriculum must be planned to introduce appropriate concepts at the proper educational levels and to develop necessary background knowledge so students can move smoothly through the metric learning process

Based on Piagetian-type tests, participants in Hawaii's pilot metrics

program concluded that students do not possess concepts necessary to understand measurement until the third grade. Thus, readiness measurement activities should be used in kindergarten and first and second grades, with formal measurement instruction beginning in the third grade and operational understanding being achieved by the end of the sixth grade. (54) Development of such concepts as "more," "less," "bigger," "smaller," etc., and of the principles of transitivity, additivity, and conservation, for example, must take place early to lay a foundation for later understanding of measurement and the metric system.

Another important curricular change will be the earlier introduction of decimals, with reinforcement of the place-value system, needed to work with metric units Students must be able to understand and compute with decimals, but until now decimals have usually been studied after common fractions. As Alan R Osborne (83) points out, a curriculum that moves directly from whole-number or integer concepts to decimals must be created and evaluated. Because fractions would be used considerably less, they would receive less treatment However, they could not be eliminated completely because, as Osborne states, students must understand nondecimal fractions in order to understand fractional numbers in all forms

In NSTA's report to the Education Conference it was noted that—

> Little is known about the effectiveness of various methods of teaching the metric system to anyone—teachers or students. There is a great need for a program of research to determine the best ways of teaching the metric system and ways of evaluating understanding and performance in the use of it. In the absence of research findings, it is believed that the most effective method for adults is to provide a concentrated period of time in which they have both extensive and intensive experience in the practical use of the metric system in a wide variety of physical measurements and in problem solving (90)

Application of the principle of actively involving the learner in the metric system is emphasized by many educators. Because learning to measure is a gradual process that is directly related to the students' experiences, instructional activities in the theory and application of metrics should relate to concrete examples Marilyn N. Suydam (97) concludes that before students can understand any system of measure, they must have experiences in measuring, and Osborne (83) calls for frequent application of metric concepts and skills in realistic problem situations, since many teachers find this use factor highly motivating Participants in Hawaii's

pilot program also found students thoroughly enjoyed measurement activities (54) George W Bright and Carolann Jones (15) also conclude that metric knowledge develops from use of the units, from repeated practice over a long period of time, providing the necessary skill and confidence

Completely involving students in the metric system is particularly important during the transition period to develop what Osborne (83) calls "metric intuition" As he points out, students require a perceptual base for learning because meaningful experience stems in part from familiarity with the perceptual environment; the more familiar the stimuli, the greater the likelihood that students will experience meaningful learning. But because students may get little experience with use of metrics outside the classroom until conversion is virtually complete throughout society, the teacher cannot assume familiarity with the system and must supplement the students' experiences by constant exposure to metrics in all subject areas As a number of groups including NEA and NSTA (90) have pointed out, the major difficulties students will face in learning and using the metric system effectively will result from the fact that it is encountered only in the classroom and not in daily living, when the metric system becomes our primary system of measurement, students should experience no significant problems with learning it. Constant exposure to metrics will lead to the familiarity that allows for a smooth metric transition.

Perhaps the most important goal of teaching the metric system is to orient students to think completely in metric terms and to de-emphasize any type of conversion or relationship between the metric and customary systems. It was noted at the Education Conference that children in elementary grades learned the metric system easily because they knew little of the customary system and experienced little of the "interference" that students familiar with customary units did. (90) In working with fourth graders, Bright and Jones (15) found conversion between systems created confusion and dislike of metrics.

Chalupsky and Crawford (19) conclude that reliance on conversion impedes instruction and that dual labeling of items in metric and customary units is a false comfort that can block new learning However, Larry R Miller (69) finds dual dimensioning to be an acceptable instructional technique to create awareness. While both metric and customary units are used during the transition, students may need to become familiar with some rule-of-thumb or approximate conversions, but teachers should

always avoid exact and complex conversion factors that will generally be used only by technicians

Related to this is the limiting of conversion *within* the metric system to commonly used units adjacent in size As the National Council of Teachers of Mathematics (NCTM) Metric Implementation Committee (76) points out, it would not generally be useful, for example, for students to convert millimeters to meters

One method proposed for getting students to think metric is the use of activities involving estimation of measurements Bright and Jones (15) find such activities motivate accuracy as students want to verify their guesses, help develop concepts of multiples, and aid in developing spatial visualization NCTM (76) sees estimating as a means of developing meaning and giving students a feeling for metric units

A final principle of metric instruction is utility Students should be taught only what they are able to grasp and what they need to know—whether for daily living, employment, or further schooling—at the appropriate educational level According to NCTM (76), only the commonly used multiples and subdivisions with their prefixes should be studied; it is better to learn the basic units thoroughly Units and their prefixes should be introduced gradually at the point they will be used, and students should not have to memorize complete tables of units that as yet have no meaning to them A complete overview of all the metric units should be presented only to older students to show the orderliness of the system and its relation to numeration. (97)

All these instructional principles can be employed in the curriculum through appropriate instructional activities. A number of writers—among them, Suydam (97) and Vincent J. Hawkins (39)—have proposed sequences of metric instruction, and the general aspects of these and other sequences will now be related to actual instructional activities.

The first steps at the elementary level should be to expose students to metric units every day and to begin to foster the skills and understandings needed for later measurement instruction Students can be introduced to concepts of size, for example, by sorting and matching objects, placing them in order by size, and comparing objects by iteration to relate measuring to counting (97) Higgins (43) also proposes comparisons of three objects to illustrate transitivity; making indirect comparisons between two objects using a third, larger object; adding lengths, areas, volumes, and masses to illustrate additivity; and transforming the shapes of objects for comparison purposes to show conservation.

The next step generally suggested is the extension of the concepts of measurement using nonstandard, arbitrary units (15, 76, 97) for estimating and measuring familiar objects to show the need for a common standard and to learn to select units appropriate to the objects being measured At this point, measuring between limits using arbitrary units shows the approximate nature of measurement and the need for smaller units for increased accuracy. By showing the logic and ease of calculations with units that relate to our decimal system, the teacher is now ready to introduce the metric system and the instruments used to measure each type of unit. (43)

Educators generally agree that metric linear measure should be taught first because it is the basic unit from which units of volume and mass are derived and because it is the easiest to understand and apply. (90) But there appears to be disagreement over the basic unit to be used. Suydam (97) prefers the centimeter over the meter at the primary level because younger students do not understand hundreds and find it difficult to handle a meter stick, Hawkins (39) would introduce meters and millimeters as early as the third grade; NCTM (76) would begin with the centimeter or decimeter at the primary level, although the meter should be introduced; Tommie A West (110) recommends the decimeter for primary grades because of its convenient size and the availability of decimeter-length materials.

Although the activities for teaching metric length and area are varied, many educators believe that students should begin with estimating West (110) suggests estimating by sorting objects into categories, searching the classroom for objects of given lengths, and guessing body measurements. Then such estimates would be verified, and actual body measurements, for example, might be recorded on a bar graph. (54, 87) A possibility in addition to estimating and measuring common objects about the classroom and playground would be a type of metric spelling bee: each child would measure and label several items in advance and then teams would attempt to estimate the metric measurements. (93) Students also might measure the classroom or playground and then prepare a map on graph paper, labeling the metric dimensions. (54)

In introducing units of mass, students could develop their understanding of *lighter, heavier*, and so on, by sorting objects according to weight and then verifying with a metric balance, Actual estimation plays less of a role with weight than with linear units, because guessing weight is more difficult and requires more maturity. (76) Suydam (97) suggests begin-

ning with the kilogram because it is easier to handle than the gram NCTM (76) would use the kilogram in the upper primary grades and the gram in the middle grades

Similar activities would be used in introducing units of capacity. Here there is generally more agreement that the liter would be the basic unit (76, 97, 110) with the milliliter introduced in the middle grades Students would be given opportunities to judge the capacity of containers, for example, and then to verify their guesses by actually filling the containers.

Also taught within the metric system would be the concepts of time, using the hour and the minute, and Celsius temperature, the latter of which NCTM (76) concludes can be introduced at any level Students could become familiar with Celsius temperature at an early age if, as William W K Freeman (33) suggests, teachers post the Celsius temperature daily together with a descriptive word such as hot, mild, bitter cold, etc , based on a combination of temperature, humidity, and seasonal and wind chill factors

Above the elementary grades, the basic knowledge of metrics is expanded and given wider application in specific subject areas Suydam (97) presents the following as appropriate objectives through the secondary level:

1 Developing relationships between measurements and between their prefixes, and converting from one metric measure to another, stressing decimal relationships
2 Introducing metric symbols, stressing correct usage, and emphasizing those for area and volume having superscripts
3 Measuring objects to the nearest millimeter, milliliter, and gram, and developing the idea of measurement accuracy and significant digits
4. Introducing computations with metric units, and working with these units to solve problems on area, perimeter, volume, time, temperature, etc.
5. Introducing metric units for problems involving force, pressure, work power, and so on as needed in mathematics, science, and vocational courses.

Hawkins' (39) instructional sequence generally follows the same progression of giving metrics more difficult applications in such subjects as geometry, trigonometry, chemistry, and physics.

The metric system can, and should, be related to essentially every subject area offered in junior and senior high schools. As described by Caravella (17):

1. Mathematics courses would be the primary source of metric knowledge to be employed in specific science courses
2. English and foreign language classes could discuss the vocabulary and symbols of the SI
3. Social studies courses would use metrics in statistics, and might discuss the history of the system, metric legislation, and the system's international use and impact.
4. Home economics courses would begin cooking and sewing with metric measures (Although cooking could still be done by volume rather than weight, Marianna Z. Cochran (22) indicates that cooking by weight helps to illustrate the value of working with whole numbers and to foster greater accuracy.)
5. Vocational education courses would work with metric units (One project described by Roy S. Hinrichs (45)—building a model racing car after appropriate metric instruction—adds the motivation of competition to metric instruction)
6. Business and art courses would use metric paper
7. Physical education classes would use metric units for weights and distances.

An example of how all these activities might be coordinated in a middle school program is presented by Thomas R Morehouse and Edwin Schoonmaker (70) In seeking an interdisciplinary approach to giving students a working knowledge of metric units, it was decided to hold a "metric month," with each department contributing: mathematics students measured the entire school in metric units, science students used metrics in all experiments and observations; English classes discussed metric terminology and used these terms in creative writing; social studies classes studied the history and sociopolitical aspects of metrics and conversion; home economics students used metrics in measuring and cooking; art students made metric posters for local stores and decorated school bulletin boards; music classes prepared metric verses for popular songs; and physical education classes held a three-day olympics contest using metric units. The authors concluded that the program not only gave students familiarity with metrics, but also created much enthusiasm. Similar endeavors at all educational levels would undoubtedly make

students more comfortable with metric units until conversion is complete throughout society.

Instructional Materials

To carry out the instructional objectives of a metric curriculum certain equipment and supplies will be needed (111) Expenditures are almost inevitable, but teachers must keep in mind instructional as well as monetary factors in deciding what must be purchased and what can be improvised or made by teachers and students from materials on hand.

Since it is not the purpose of this report to recommend specific instructional materials, some practical guidelines for selecting such materials are outlined for the classroom teacher. West (110) cautions against using commercial meter sticks with younger children because they give too much information, and Barbara Pottinger (87) finds many current materials too advanced for third graders. The advantage of using audiovisual materials, particularly until conversion is complete, is stressed by Lottie E Mackay (58) because they can be produced more quickly and in smaller instructional segments than complete textbooks series, for example, and because they can be rented rather than purchased.

Higgins (42) points out that metric materials will probably be more expensive than customary materials for some time to come, and hence, recommends that teachers purchase some good-quality materials to use as metric standards and improvise to meet the rest of their needs. Many educators, however, warn of the importance of evaluating commercial materials carefully before purchase Chalupsky and Crawford (19) relate the experience of Great Britain and other countries in converting to metrics:

> The intense demand for metric materials generates a flood of inaccurate and inadequate products. Materials produced under pressure to meet the new demands frequently contain serious errors They are often unsuitable for classroom use and are not related to any explicit teaching/learning objectives. A common oversight overseas was the failure to provide for materials evaluation until classrooms were loaded with ineffective and error-laden junk. The U.S appears to be heading rapidly toward a similar plight. There is a rising tide of new materials but a general lack of evaluation efforts. As overseas staffs became experienced in metric instruction, they discovered many ways to produce inexpensive, teacher-made, and student-made materials. For them, it was a slow

trial-and-error process. U.S. educators can capitalize on this achievement.

Hawkins (38) is concerned that materials producers may become too rushed in attempting to fill the increasing demand for metric aids and may thus become careless, providing inaccurate and incomplete materials that might not be suitable for use with students. T. K. Muellen (71) advises that "the purchase of very many materials will not be necessary. Danger exists in the acceptance of the time-honored pressure to buy expensive teaching aids of questionable value when items which we have around us in everyday life are available."

As a means of ensuring that purchased materials will readily aid the teacher and the student, Chalupsky (18) suggests evaluating them in terms of their technical accuracy, the quality of the materials and their construction, the instructional effectiveness and the validity and testing of the materials, the development of measurement skills, the promotion of metric awareness and a favorable attitude toward the system, the interest and difficulty levels, the freedom from reliance on conversion between systems, and the adequacy of accompanying teaching guides.

Donovan (29) reports that results in Great Britain's primary grades with student-made metric equipment such as cardboard meter sticks were favorable. The Suggested Readings contain numerous ideas and instructions for creating the metric materials needed, particularly at the elementary level. Among them are the following:

Length and area: Adding machine or cash register tapes can be cut into meter lengths and folded into 10 parts to make decimeters. A meter board one centimeter thick, one decimeter wide, and one meter long can be fabricated and then split into decimeter segments linked with magnets so it can be stacked as a cubic decimeter or liter. Cuisenaire rods, already in many classrooms, are one centimeter square and one to ten centimeters long, making them handy measuring tools for younger students. Lottie Viets (108) describes the contents of a kit of metric units students can collect or make including a string or ribbon one meter long, decimeter-long soda straws strung on a meter-long piece of yarn, and a cardboard meter stick. To help students estimate area, the teacher can take graph paper with two-millimeter squares and rule off square centimeters so the sheets can be placed over the objects to be estimated.

Weight and mass: Because the gram is a fairly small unit, many older balances may not be sensitive enough to weigh grams with accuracy. If a good metric balance cannot be borrowed from a science classroom,

Higgins (42) provides instructions for building a simple and inexpensive balance, and weights such as nickels, weighing five grams, and paper clips, weighing one gram, can be used. The classroom abounds with familiar objects that the students can weigh, or items might be brought from home

Volume and capacity: Since the bottom of a half-gallon milk carton is a square decimeter, it can be cut to make a cubic decimeter or liter measure Plastic jugs, buckets, or cups can be marked in deciliter units or liter units, and test tubes can be calibrated in milliliters for older students Common materials such as sand and rice can be used to fill the containers as the students estimate and measure capacity.

Temperature: Fahrenheit thermometers can be recalibrated to the Celsius scale, although Higgins (42) cautions that this approach is useful but not completely accurate

Ron Fisher (32) suggests developing students' investigative and observational as well as measurement skills by stocking a "measurement corner" of the classroom with such materials and suggested activities

One type of metric instructional aid deserving special attention is the metric game Educational games have increased in popularity because of both effectiveness and motivation. ~~Cecil R~~ Trueblood and Michael Szabo (101) discuss seven steps developed by elementary teachers to be followed in creating metric games.

1. Write down the skills the student is to learn, such as observing, measuring, or classifying.
2. Develop the materials for the game, keeping them simple and relatively sturdy
3. Write down the rules and procedures for the game. (This is essential to the self-instructional nature of the game.) They should be simple and straightforward to keep the game moving.
4. Decide how feedback will be handled—a key feature in an educational game because of its motivational as well as instructional impact, since the students want to verify their answers. Also, decide how students will record diagnostic information for future evaluation.
5. Provide an element of chance to create suspense for the players.
6. Select features that can be altered easily to vary the focus of the game.
7. Find out how students react to the game and evaluate the learning that results from it

As an example of the application of these procedures, the authors describe a game designed to give students practice with estimation, measurement, and computation Equipment includes a game board with squares on which the students advance their markers by rolling dice three sets of numbered task cards (one for each of the previously mentioned skills) with answers and points to be awarded on the back, a metric balance, common objects weighing between one and seven kilograms, and student record cards. Two to six players roll the dice, and advance around the board, selecting a task card from the stack indicated by the square in which they land If the task is done correctly, the student enters the number of the task, the answer, and the points received on her/his record card. The first player to circle the board with the most points wins. Feedback is immediate since answers are provided on the task cards. Record cards are given to the teacher to help her/him evaluate both the progress of the players and the effectiveness of each of the tasks. Suspense is added since students get extra points, lose points, or move forward or backward when they land on certain squares. The game also can be altered by adding new task cards for estimation, measurement, and computation with linear and area measurement

Pottinger (87) also has made use of metric games as part of a metric "lab" culminating an instructional unit on metrics; in fact, one of the activities was actually making some of the games. Among the games used were a card game involving memory to match metric equivalents and picture board games with measurement activities and problems to solve Pottinger found that such exercises helped students see the relationships between units of measurement, improved their ability to estimate, and increased their enthusiasm

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American Metric Journal
AMJ Publishing Company
Drawer L
Tarzana, Calif 01356

American National Metric Council
(*Metric Reporter*)
1625 Massachusetts Avenue, N.W.
Washington, D C 20036

American National Standards Institute
1420 Broadway
New York, N Y 10018

Metric Association
Sugarloaf Star Route
Boulder, Colo 80302

Metric Information Office
National Bureau of Standards
Washington, D C 20234

Metric Studies Center
American Institutes of Research
P O Box 1113
Palo Alto, Calif 94302

Metrication Task Group
George C Marshall Space Flight Center
Huntsville, Ala 35812

National Council of Teachers of Mathematics
1906 Association Drive
Reston, Va 22091

National Microfilm Association
8728 Colesville Road
Silver Spring, Md. 20910

National Science Teachers Assn
1742 Connecticut Avenue, N W.
Washington, D C 20009

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